PATHOGENS AND CHEMICALS TESTED AGAINST CATERPILLARS ON CABBAGE

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Contents

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PATHOGENS AND CHEMICALS TESTED AGAINST CATERPILLARS ON CABBAGE

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Pests of cabbage in the Charleston, S.C., area include the cabbage looper (*Trichoplusia ni* Hübner)), the imported cabbageworm (*Pieris rapae* (L.)), the diamondback moth (*Plutella maculipennis* (Curtis)), and the fall armyworm (*Spodoptera frugiperda* (J. E. Smith)). The imported cabbageworm and the diamondback moth are present in damaging numbers on spring-grown cabbage, the fall armyworm on fall-grown cabbage, and the cabbage looper on both.

Of these caterpillars, only the cabbage looper is difficult to control with registered insecticides. These insecticides in some instances have been totally ineffective against this pest, allowing it to feed extensively on the heads and wrapper leaves and thus render them unfit for market. Chalfant and Brett (*1*)[2] reported in 1965 that there was no completely suitable registered insecticide for controlling this insect on cabbage in North Carolina.

Cabbage looper populations are often reduced substantially during the fall by epizootics of fungi and virus and by parasites and predators. This is probably one reason why in the Charleston area it is usually easier to control this insect during the fall than in the spring with the registered chemical insecticides.

Materials are urgently needed that will adequately control the cabbage looper but at the same time will be harmless to man, parasites, and predators and impart no objectionable residues or flavors to the crop. Primarily for this reason tests were conducted during 1963–68 at Charleston with the bacteria *Bacillus thuringiensis* var. *thuringiensis* and *B. thuringiensis* var. *galleriae* Berliner and with a cabbage looper nuclear polyhedrosis virus. These treatments were compared to standard chemical insecticides.

REVIEW OF LITERATURE

Bacillus thuringiensis has been shown to be effective against the imported cabbageworm (*2, 6, 8, 12*). However, results in field experiments have been variable (*1, 2, 5, 6, 8, 10*).

Hall (*4*) applied inoculum from virus-infected loopers to field plots of lettuce infested with the cabbage looper. Virus concentrations of 5×10^6 and 1×10^7 polyhedra per milliliter applied at the rate of 12 gallons per acre resulted in almost 100 percent mortality of the larval population. McEwen and Hervey (*7*) initiated polyhedrosis epizootics in plots of cauliflower, cabbage, and broccoli with 0.94 to 120 diseased larvae per acre. In New York, Semel (*11*) effectively controlled cabbage loopers on cauliflower with virus sprays of 10 infected larvae per acre. Getzin (*3*) obtained more effective looper control on cabbage with 9.5×10^{11} than with 9.5×10^9 polyhedra per acre.

MATERIALS AND METHODS

The *B. thuringiensis* formulations A and AA were liquids containing 30 and 15 billion spores per gram, respectively. The B, BB, and C formulations were wettable powders containing 25, 25, and 75 billion spores per gram, respectively. The D and E formulations were dusts, each with 2.5 billion spores per gram. All were commercial bacillus formulations. The raw and semipurified virus preparations were liquids with 11 and 17 billion viral polyhedra per milliliter, respectively. The oils were commercial preparations of refined white corn oil and mineral oil. The Lovo 192, an amine stearate mixture plus alcohols, was a commercially prepared liquid spray additive. The

[1] The authors are grateful for the assistance of the following persons in this Division: R. J. Hamalle for preparing the virus material used in the 1967 tests, Mrs. E. D. Welch for statistical analysis of the data, and R. B. Cuthbert, Jr., J. R. Glover, and J. Richardson for conducting the field tests.

[2] Italic numbers in parentheses refer to Literature Cited, p. 10.

chemical insecticides were emulsifiable concentrates of endosulfan, mevinphos, naled, and parathion.

The polyhedral virus suspension was obtained by feeding virus-treated foliage to large numbers of late-instar cabbage looper larvae. The virus-diseased larvae were collected shortly before they died, placed in distilled water, and held at room temperature long enough to putrefy them. The material was triturated thoroughly in a Waring blender and then strained through several layers of cheesecloth. Polyhedra counts were made with an improved Neubauer-ruling hemacytometer under oil immersion. The virus suspension was stored in the refrigerator until used. The virus material prepared in this manner was considered to be in a raw state and was used in all tests conducted in 1963 through 1966. However, the virus material used in 1967 was semipurified by washing and centrifugation.

All tests were conducted in randomized block designs at the South Carolina Agricultural Experiment Station. In 1963–65, treatments were replicated six times. Each replicate consisted of a single 3- by 50-foot row of cabbage plants separated from adjacent replicates by a single cabbage row. All treatments were applied with knapsack sprayers. In 1966–68, treatments were replicated either four or six times. The test plots sprayed with knapsack sprayers consisted of four rows of cabbage plants, 12 by 25 feet. The plots sprayed with a tractor-mounted sprayer had four rows of plants, 12 by 50 feet. All plots were separated laterally by two rows of snap beans.

All sprays were applied at 50 gallons per acre unless otherwise denoted. The spreader-sticker Triton B 1956 was added to each spray at 1 ml. per gallon of spray in tests conducted in 1963 through the spring of 1966 and at 4 ml. per gallon in the fall of 1966. In 1967 and 1968 the spreader-sticker Plyac was included in the sprays as well as Triton B 1956. Each was used at 4 ml. per gallon of spray.

In the 1964 spring tests, treatments were preceded by two applications of a spray containing toxaphene at 2.5 pounds and parathion at 0.5 pound per acre. In the 1965 spring tests, treatments were preceded by one application each of mevinphos at 0.5, parathion at 0.5, and endosulfan at 0.75 pound per acre.

Treatments were made at approximately 7-day intervals, or at alternating 3- and 4-day intervals when there were more than seven applications. Spring treatments generally were begun in early May and extended into early June. Fall treatments usually were started during the last part of September and extended into the last week of October or the first week of November. Sprays were applied only to dry foliage when the wind velocity was under 4 m.p.h. Dusts were applied with rotary hand dusters at daybreak when the wind velocity was 0 m.p.h. as recorded by an anemometer. For adequate coverage, the sides and tops of the plants were treated.

Effectiveness of the treatments was determined by counting the surviving larvae and pupae of each species on 10 plants of each plot after treatment and estimating the extent of caterpillar injury to the marketable part of the plant at harvest. A classification system (*9*) was used to estimate the amount of injury due to feeding. Plants with firm heads and four wrapper leaves free of visible caterpillar feeding were in class 1. Class 3 plants had firm heads and four wrapper leaves sufficiently damaged by caterpillars to be ineligible for U.S. Grade 1.

Treatments giving adequate or effective plant protection were considered to be those that protected the marketable parts of the plant to the extent that not more than 6 percent of the plants were classified as damaged (class 3). It is possible, of course, for a treatment to effectively control one or more target species but fail to provide adequate plant protection because it did not control all the species present.

SEASONAL POPULATIONS OF CABBAGE LOOPER

The cabbage looper populations found on untreated plots during the spring and fall tests are given in figures 1 and 2.

In the spring tests the highest populations occurred during 1964 and 1965. The lowest infestations were in 1963 (test 1), 1967 (test 3), and 1968. The peak populations in 1963, 1964, 1965, and 1968 occurred during the last week of May or the first week of June; however, in 1966 and 1967 they were during mid-May.

In the fall tests the looper populations in 1963 were about the same as in the spring of that year. In 1964 and 1967, populations in the fall were considerably lower, and in 1966 they were slightly higher than in the spring. Sometimes the peak populations occurred during the middle and last part of September and at other times during the last part of October and early November. The lowest infestations recorded were in 1964 and 1967.

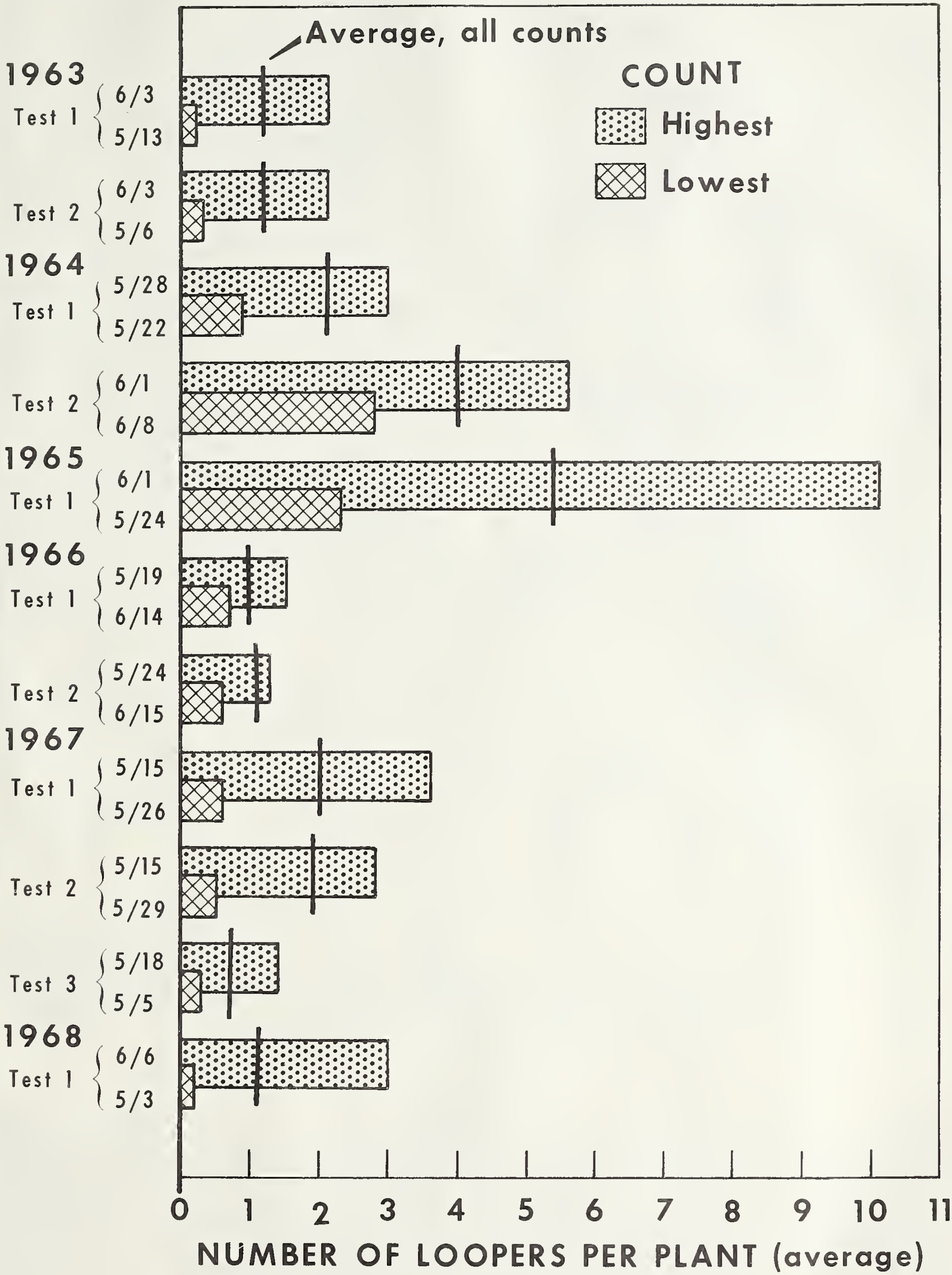

FIGURE 1.—Cabbage looper populations during spring tests.

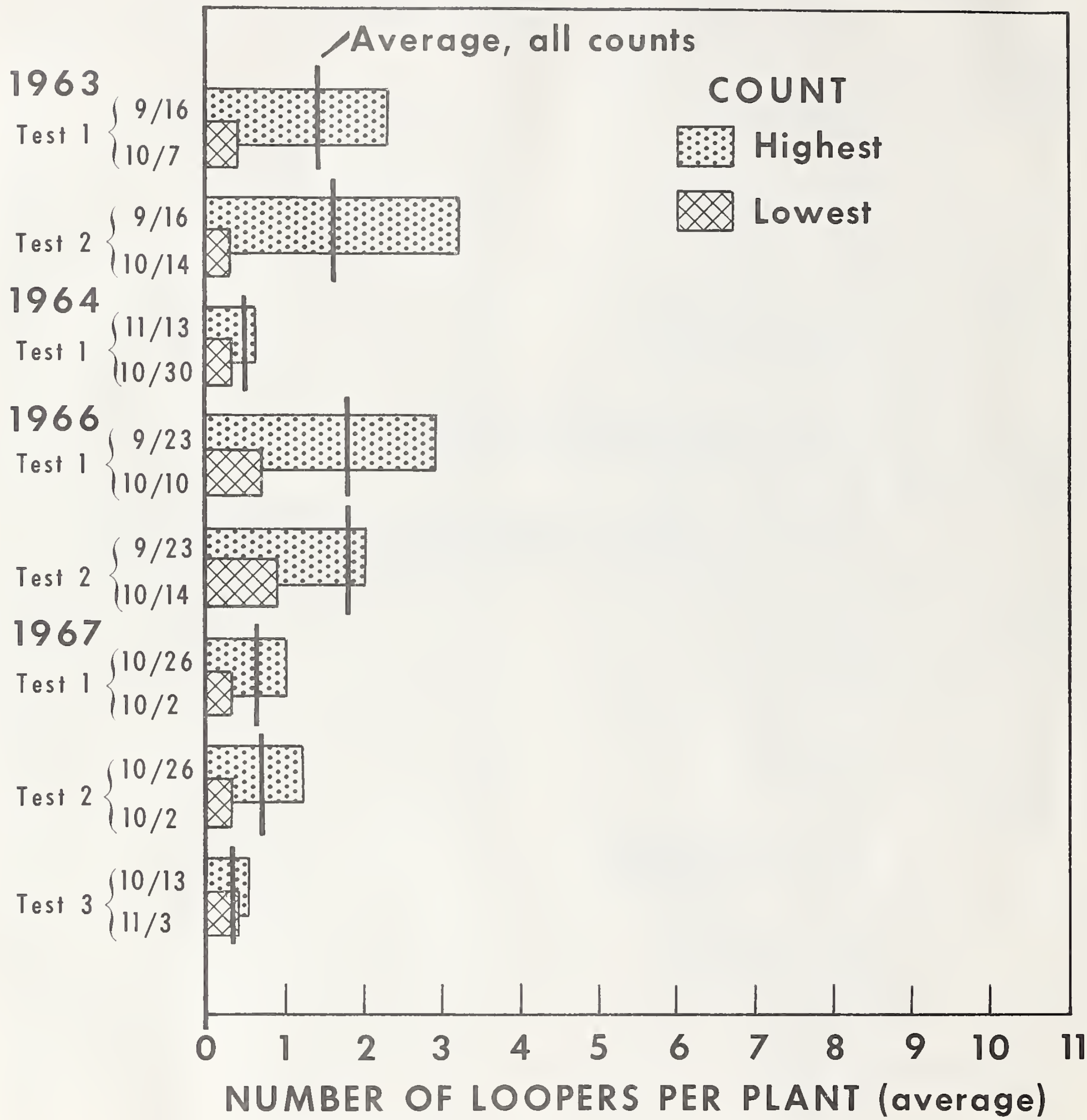

FIGURE 2.—Cabbage looper populations during fall tests.

RESULTS

The number of cabbage looper larvae and pupae that survived the various treatments is summarized in tables 1 and 2. Control of this insect was necessary for adequate crop protection, and the degree of control determined to a large extent the percent of damaged plants (class 3). Bacillus alone gave 0–68 percent control ($\bar{x}=36$ percent) in the spring and 3–80 percent control ($\bar{x}=51$ percent) in the fall. The bacillus dust formulation E at 40 pounds per acre provided excellent control (98 percent) in both the spring and the fall of 1967. The treatments with virus alone gave 20–77 percent control ($\bar{x}=54$ percent). Sprays containing both bacillus and virus usually provided better control than sprays with only bacillus. They gave

32–91 percent control ($\bar{x}=66$ percent) in the spring and 57–80 percent control ($\bar{x}=69$ percent) in the fall. The chemical insecticides were apparently equally effective in the spring and the fall. Treatments with endosulfan, mevinphos, naled, and parathion alone gave 26–88 percent control ($\bar{x}=57$ percent), but the combination treatment of endosulfan plus parathion gave 73–97 percent control ($\bar{x}=90$ percent) of cabbage loopers.

The number of larvae and pupae of the imported cabbageworm and the diamondback moth that survived the various treatments is summarized in table 1. Virus alone did not affect the imported cabbageworm at 5×10^{10} polyhedra per acre in 1964 (test 2) but caused some mortality at 1×10^{11} polyhedra and greater mortality at 1×10^{12} polyhedra in 1965. The diamondback moth did not develop significant infestations in 1964 and 1965, the two seasons in which the virus alone was tested. In general, all the treatments containing either bacillus or chemical insecticide, either alone or in some combination, drastically reduced the numbers of both the imported cabbageworm and the diamondback moth. For this reason, the data do not indicate whether the treatments were enhanced by the addition of virus.

The number of fall armyworm larvae and pupae that survived the various treatments is summarized in table 2. Bacillus alone generally gave only moderate control but was as effective as the standard insecticides in 1967 when it was used in dust form. The effectiveness of the bacillus spray was apparently not enhanced by the addition of molasses or Plyac. The treatments with virus alone had no significant effect, but the effectiveness of bacillus was significantly reduced by the addition of the virus: In 1963, bacillus reduced the population by 55 percent compared to only 18 percent with the bacillus-virus mixture. In 1966, bacillus alone gave an average control of 78 percent compared to only 27 percent with the bacillus-virus mixture. In all tests chemical insecticides gave 73–100 percent control ($\bar{x}=90$ percent) and were equal or superior to the pathogens for control of the fall armyworm.

The overall effectiveness of the treatments against the complex of target insect pests was indicated by the percent of injured plants shown in tables 1 and 2. The bacillus used alone in sprays generally reduced damage by 12–89 percent ($\bar{x}=59$ percent). However, treatments in 1967 (fall) with 4 pounds per acre of formulation B gave 87–93 percent control ($\bar{x}=91$ percent), and in 1968 (spring) a treatment with 4 quarts per acre of formulation A

TABLE 1.—*Relative effectiveness of pathogens and chemicals as insecticides against caterpillars on spring cabbage at Charleston, S.C., 1963–68* [1]

Year, test, and treatment per acre	Applications	Average per 100 plants of surviving larvae and pupae of— Cabbage looper	Imported cabbageworm	Diamondback moth	Plants in— Class 1 [2]	Class 3 [2]
	Number	*Number*	*Number*	*Number*	*Percent*	*Percent*
1963, test 1						
Bacillus A, 1 qt	6	140 c	17 a	19 b	3 b	54 b
Bacillus A, 1 qt., plus virus, 5×10^{11} polyhedra	6	69 b	1 a	16 ab	7 b	14 a
	12	28 a	1 a	9 ab	52 a	2 a
Parathion, 0.5 lb	6	15 a	2 a	2 a	49 a	8 a
Untreated		118 c	136 b	74 c	0 b	98 c
1963, test 2						
Bacillus A, 1 qt	6	88 bc	4 a	15 a	0 c	68 d
Bacillus A, 1 qt., plus—						
Corn oil, 1 qt	6	85 bc	5 a	13 a	1 c	49 abc
Mineral oil, 1 qt	6	76 b	4 a	12 a	0 c	52 bc
Naled, 2 lb	6	36 a	4 a	12 a	3 c	40 ab
Bacillus A, 2 qt	6	95 bc	9 a	14 a	1 c	57 cd
Bacillus A, 4 qt	6	83 bc	6 a	12 a	3 c	34 a
Naled, 2 lb	6	43 a	1 a	11 a	7 b	39 ab
Parathion, 0.5 lb	6	33 a	4 a	3 a	13 a	33 a
Untreated		118 c	182 b	116 b	0 c	100 e

See footnotes at end of table.

TABLE 1.—*Relative effectiveness of pathogens and chemicals as insecticides against caterpillars on spring cabbage at Charleston, S.C., 1963–68* [1]—Continued.

Year, test, and treatment per acre	Applications	Average per 100 plants of surviving larvae and pupae of— Cabbage looper	Imported cabbage-worm	Diamond-back moth	Plants in— Class 1 [2]	Class 3 [2]
	Number	*Number*	*Number*	*Number*	*Percent*	*Percent*
1964, test 1						
Bacillus A, 1 pt	3	179 cd	0	--------	0 e	53 f
Bacillus A, 1 pt., plus—						
Mevinphos, 0.25 lb	3	121 ab	0	--------	5 b	39 b–f
Naled, 1 lb	3	104 a	0	--------	3 de	43 c–f
Bacillus A, 1 qt	3	166 bcd	0	--------	0 e	48 ef
Bacillus B, 1.2 lb	3	106 a	0	--------	5 b	31 a–d
Bacillus B, 1.2 lb., plus—						
Lovo 192, 0.1 gal	3	122 ab	0	--------	1 e	24 ab
Mevinphos, 0.25 lb	3	97 a	0	--------	2 e	28 ab
Naled, 1 lb	3	122 ab	0	--------	4 bcd	32 a–d
Bacillus B, 2.4 lb	3	96 a	0	--------	2 de	31 a–d
Bacillus B, 2.4 lb., plus Lovo 192, 0.1 gal	3	88 a	0	--------	8 a	21 a
Mevinphos, 0.25 lb	3	119 ab	0	--------	1 e	44 def
Untreated		210 d	5	--------	0 e	75 g
1964, test 2						
Bacillus A, 1 pt., plus—						
Virus, 1 × 10 [12] polyhedra	3	158 a–d	3	--------	30 a	6 a
Virus, 5 × 10 [10] polyhedra	3	235 ef	2	--------	2 c	22 bcd
Bacillus B, 1.2 lb., plus						
Virus, 1 × 10 [12] polyhedra	3	168 a–e	0	--------	34 a	2 a
Virus, 5 × 10 [10] polyhedra	3	271 f	0	--------	5 c	11 ab
Virus, 5 × 10 [10] polyhedra	3	211 b–f	17	--------	3 c	34 de
Virus, 5 × 10 [10] polyhedra, plus—						
Lovo 192, 0.1 gal	3	213 c–f	17	--------	1 c	38 e
Mevinphos, 0.25 lb	3	117 a	0	--------	19 b	12 ab
Naled, 1 lb	3	141 abc	0	--------	10 bc	14 ab
Naled, 1 lb	3	232 def	0	--------	3 c	33 cde
Untreated		403 g	15	--------	0 c	79 f
1965 test						
Bacillus B, 1.2 lb	3	255 abc	13 a	--------	--------	86 cd
Bacillus B, 1.2 lb., + virus, 1 × 10 [12] polyhedra	3	225 ab	17 a	--------	0	67 b
Virus, 1 × 10 [11] polyhedra, at 5 gal	3	379 bc	108 c	--------	0	98 d
Virus, 1 × 10 [11] polyhedra, + mevinphos, 0.5 lb., at 5 gal	3	213 ab	13 a	--------	3	63 b
Virus, 1 × 10 [12] polyhedra	3	270 abc	71 b	--------	0	90 d
Virus, 1 × 10 [12] polyhedra, + mevinphos, 0.5 lb	3	257 abc	8 a	--------	5	36 a
Endosulfan, 1 lb	3	170 a	56 a	--------	0	74 bc
Mevinphos, 0.5 lb	3	236 abc	13 a	--------	3	64 b
Mevinphos, 0.5 lb., at 5 gal	3	400 cd	27 a	--------	0	87 cd
Untreated		540 d	159 d	--------	0	98 d
1966, test 1						
Bacillus A, 1 qt	6	55 d	4 a	5 a	3 c	32 d
Bacillus A, 1 qt., + virus, 6 × 10 [12] polyhedra	6	21 bc	2 a	4 a	38 b	4 a
	9	9 ab	4 a	1 a	53 a	0 a
Bacillus B, 1 lb	6	56 d	2 a	2 a	4 c	27 c
Bacillus B, 1 lb., plus—						
Virus, 3 × 10 [12] polyhedra	6	32 c	8 a	2 a	11 c	15 b
Virus, 6 × 10 [12] polyhedra	6	10 ab	4 a	3 a	34 b	3 a
Endosulfan, 1 lb., + parathion, 0.5 lb	6	3 a	0 a	2 a	61 a	2 a
Untreated		102 e	68 b	11 b	0 c	88 e

See footnotes at end of table.

TABLE 1.—*Relative effectiveness of pathogens and chemicals as insecticides against caterpillars on spring cabbage at Charleston, S.C., 1963–68* [1]—Continued.

Year, test, and treatment per acre	Applications	Average per 100 plants of surviving larvae and pupae of—			Plants in—	
		Cabbage looper	Imported cabbage-worm	Diamond-back moth	Class 1 [2]	Class 3 [2]
	Number	*Number*	*Number*	*Number*	*Percent*	*Percent*
1966, test 2						
Bacillus A, 1 pt	5	40 bc	10 a	2 a	0 c	65 c
Bacillus A, 1 pt., + virus, 6 × 10¹² polyhedra	5	30 ab	0 a	2 a	9 ab	21 a
Bacillus B, 2 lb	5	50 cd	10 a	3 a	1 c	48 b
Endosulfan, 1 lb	5	40 bc	20 a	3 a	3 bc	46 b
Endosulfan, 1 lb., + virus, 2 × 10¹² polyhedra	5	10 a	0 a	2 a	15 a	24 a
Untreated		70 d	60 b	9 b	1 c	87 d
1967, test 1						
Bacillus A, 2 qt	6	82 c	1 a	4 a	7 c	20 b
Bacillus AA, 1 qt	6	89 c	1 a	2 a	3 c	20 b
Bacillus AA, 1 qt., plus—						
Virus, 6 × 10¹¹ polyhedra	6	68 bc	3 a	3 a	22 b	7 ab
Virus, 6 × 10¹² polyhedra	6	31 ab	0 a	4 a	47 a	6 ab
Endosulfan, 1 lb., + parathion, 0.5 lb	6	18 a	0 a	0 a	51 a	4 a
Untreated		202 d	18 b	14 b	0 c	66 c
1967, test 2						
Bacillus AA, 1 qt., + virus, 6 × 10¹¹ polyhedra	6	52 b	0 a	6 ab	26 c	9 a
Bacillus B, 2 lb., + virus, 6 × 10¹¹ polyhedra	6	42 b	0 a	3 a	30 c	7 a
Bacillus D, 40 lb	6	151 c	8 b	15 b	0 d	26 b
Bacillus E, 40 lb	6	4 a	0 a	1 a	88 a	0 a
Endosulfan, 1 lb., + virus, 6 × 10¹¹ polyhedra	6	12 a	0 a	0 a	64 b	7 a
Untreated		188 d	17 c	25 c	0 d	77 c
1967, test 3						
Bacillus B, 4 lb., plus—						
Plyac, 0.1 gal	6	109 ab	1 a	3	7 bc	17 a
Plyac, 0.1 gal., + corn sirup, 1 gal	6	111 ab	0 a	1	8 bc	11 a
Plyac, 0.1 gal., + molasses, 1 gal	6	72 a	0 a	3	29 a	10 a
Triton B 1956, 0.1 gal	6	134 b	1 a	5	5 bc	14 a
Triton B 1956, 0.1 gal., + corn sirup, 1 gal	6	105 ab	0 a	1	13 b	14 a
Mevinphos, 0.5 lb	6	56 a	0 a	0	10 bc	19 a
Untreated		126 b	15 b	4	0 c	64 b
1968 test						
Bacillus A, 1 qt., + parathion, 0.5 lb	6	39 ab	--------	4 a	7 d	38 c
Bacillus A, 2 qt	6	34 ab	--------	18 a	27 c	14 ab
Bacillus A, 4 qt	6	22 ab	--------	9 a	40 b	6 a
Bacillus BB, 1 lb., + parathion, 0.5 lb	6	39 b	--------	4 a	7 d	33 c
Bacillus BB, 2 lb	6	26 ab	--------	11 a	33 bc	15 ab
Bacillus BB, 4 lb	6	28 ab	--------	9 a	27 c	15 ab
Bacillus E, 25–30 lb	6	12 a	--------	2 a	58 a	6 a
Endosulfan, 1 lb., + parathion, 0.5 lb	6	19 ab	--------	4 a	28 bc	16 b
Untreated		69 c	--------	68 b	0 d	90 d

[1] Values within columns without same letter are significantly different at 5-percent level as determined by Duncan's multiple range test.

[2] Class 1 = plants with firm heads and 4 wrapper leaves free of visible caterpillar feeding; class 3 = plants with firm heads and 4 wrapper leaves sufficiently damaged to be ineligible for U.S. Grade 1.

gave 93 percent control. In 1967 (fall) the bacillus dust formulation E at 20 and 40 pounds per acre resulted in 97 and 100 percent control, respectively. In 1968 this same dust formulation when used at 25–30 pounds per acre gave 93 percent control. The virus treatments alone reduced damage by 0–58 percent ($\bar{x}=35$ percent). The chemical treatments gave 11–91 percent control ($\bar{x}=47$ percent) in spring tests and 72–82 percent control ($\bar{x}=77$ percent) in fall tests, but the combination treatment of endosulfan plus parathion produced 82–100 percent control ($\bar{x}=93$ percent) in all tests.

The combination of bacillus with mevinphos, naled, or parathion did not enhance control as much as was expected. Since the effects of virus were additive to the effects of the other treatments, the addition of virus to bacillus or insecticide treatments provided greater plant protection than could be achieved with any treatment used alone.

The results demonstrate that effective control of the caterpillar complex on cabbage can be achieved with a mixture of the bacterium *Bacillus thuringiensis* and the cabbage looper nuclear polyhedrosis virus. Cabbage looper control with one bacillus dust formulation and with combination sprays containing either bacillus and virus or virus and certain registered insecticides was especially encouraging.

TABLE 2.—*Relative effectiveness of pathogens and chemicals as insecticides against caterpillars on fall cabbage at Charleston, S.C., 1963–67* [1]

Year, test, and treatment per acre	Applications	Average per 100 plants of surviving larvae and pupae of—		Percentage of plants in—	
		Cabbage looper	Fall armyworm	Class 1 [2]	Class 3 [2]
	Number	*Number*	*Number*	*Percent*	*Percent*
1963, test 1					
Bacillus A, 1 pt	11	116 c	11 ab	23 bcd	17 ab
Bacillus A, 1 pt., + virus, 5 × 10^{11} polyhedra	11	35 a	22 abc	56 a	8 a
Bacillus A, 1 qt	6	136 c	14 abc	15 cd	19 ab
Bacillus A, 1 qt., + virus, 1 × 10^{12} polyhedra	6	52 ab	19 abc	42 ab	11 ab
Virus, 1 × 10^{12} polyhedra	6	36 a	22 abc	26 bcd	22 b
Virus, 5 × 10^{11} polyhedra	11	32 a	28 abc	32 bc	15 ab
Parathion, 0.5 lb	6	75 b	7 a	38 b	10 a
Untreated		140 c	24 bc	13 d	36 c
1963, test 2					
Bacillus A:					
2 qt	6	178 b	----------	12 bc	25 b
4 qt	6	140 ab	----------	30 b	21 b
Bacillus C, 8 lb	6	78 a	----------	54 a	8 a
Untreated		201 b	----------	3 c	47 c
1964 test					
Bacillus A, 1 qt	7	38 b	----------	27 c	41 c
Bacillus B, 2.4 lb	7	17 a	----------	47 b	13 ab
Bacillus B, 2.4 lb., + mevinphos, 0.5 lb	7	11 a	----------	78 a	5 a
Endosulfan, 0.75 lb	7	21 ab	----------	57 b	10 a
Mevinphos, 0.5 lb	7	14 a	----------	60 ab	12 ab
Untreated		54 b	----------	11 d	56 d
1966, test 1					
Bacillus AA, 1 qt	7	112 b	13 ab	8 c	43 c
Bacillus AA, 1 qt., + virus, 6 × 10^{11} polyhedra	7	76 b	34 bc	22 b	30 b
Virus, 6 × 10^{11} polyhedra	7	90 b	53 c	10 c	38 bc
Endosulfan, 1 lb., + parathion, 0.5 lb	7	27 a	0 a	78 a	6 a
Untreated		177 c	45 c	4 c	61 d
1966, test 2					
Bacillus A, 2 qt	7	35 a	----------	29 b	23 a
Bacillus AA, 1 qt., + virus, 6 × 10^{11} polyhedra	7	41 a	----------	28 b	24 a
Bacillus AA, 2 qt	7	44 a	----------	26 b	25 a
Endosulfan, 1 lb., + parathion, 0.5 lb	7	8 a	----------	88 a	3 a
Untreated		145 b	----------	2 c	68 b

See footnotes at end of table.

TABLE 2.—*Relative effectiveness of pathogens and chemicals as insecticides against caterpillars on fall cabbage at Charleston, S.C., 1963–67* [1]—Continued.

Year, test, and treatment per acre	Applications	Average per 100 plants of surviving larvae and pupae of— Cabbage looper	Fall armyworm	Percentage of plants in— Class 1 [2]	Class 3 [2]
	Number	*Number*	*Number*	*Percent*	*Percent*
1967, test 1					
Bacillus E:					
20 lb	7	14 a	5 a	86 a	1 a
40 lb	7	1 a	1 a	92 a	0 a
Endosulfan, 1 lb., + parathion, 0.5 lb	7	3 a	1 a	88 a	3 a
Untreated		63 b	23 b	17 b	48 b
1967, test 2					
Bacillus A, 2 qt	7	28 b	4 ab	48 a	14 b
Bacillus AA, 2 qt	7	14 ab	2 ab	62 a	9 ab
Bacillus B, 2 lb., + virus, 6×10^{12} polyhedra	7	14 ab	9 b	58 a	6 a
Bacillus B, 4 lb	7	22 ab	2 ab	58 a	6 a
Endosulfan, 1 lb., + parathion, 0.5 lb	7	6 a	1 a	60 a	0 a
Untreated		67 c	16 c	3 b	66 c
1967, test 3					
Bacillus B, 4 lb., plus—					
Molasses, 1 gal	6	14 ab	1 a	90 a	2 a
Molasses, 2 gal	6	9 a	4 a	86 a	2 a
Plyac, 0.1 gal	6	7 a	4 a	86 a	4 a
Untreated		26 b	17 a	35 b	31 b

[1] Values within columns without same letter are significantly different at 5-percent level as determined by Duncan's multiple range test.

[2] Class 1 = plants with firm heads and 4 wrapper leaves free of visible caterpillar feeding; class 3 = plants with firm heads and 4 wrapper leaves sufficiently damaged to be ineligible for U.S. Grade 1.

SUMMARY

Research was undertaken at Charleston, S.C., during the spring and fall of 1963–68 to determine the efficacy of various pathogens and chemicals for control of caterpillars on field-grown cabbage. Tests were conducted with the bacteria *Bacillus thuringiensis* var. *thuringiensis* and *B. thuringiensis* var. *galleriae* Berliner and a cabbage looper nuclear polyhedrosis virus against the following pests of cabbage: Cabbage looper (*Trichoplusia ni* (Hübner)), imported cabbageworm (*Pieris rapae* (L.)), diamondback moth (*Plutella maculipennis* (Curtis)), and fall armyworm (*Spodoptera frugiperda* (J. E. Smith)).

Sprays containing only bacillus were generally effective against these last three insects but failed to provide adequate control of the cabbage looper. However, a bacillus dust formulation tested for the first time in 1967 effectively controlled all four pest species. Plant protection with this formulation in 1967 was as good as that with a conventional spray containing endosulfan plus parathion, and in 1968 this dust treatment was significantly better than the spray.

Sprays containing only virus were effective against the cabbage looper, but did not control the other insect species.

Sprays with both bacillus and virus usually were significantly better than bacillus alone for control of the cabbage looper and were slightly better than virus alone. However, control of the fall armyworm was significantly reduced by adding virus to the bacillus spray. Nevertheless, the sprays containing both bacillus and virus always provided significantly better plant protection against the caterpillar complex than either material used alone. A spray with bacillus plus virus at 6×10^{12} polyhedra per acre gave protection comparable to that with an endosulfan-parathion spray.

The efficacy of mevinphos, naled, or parathion sprays was not improved by adding bacillus. However, control of the cabbage looper was enhanced by adding virus to sprays containing endosulfan, mevinphos, or naled.

Several liquid spray additives, including a spreader-sticker, failed to improve the efficacy of the pathogen sprays.

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